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Water Management Information System for the Rio Bravo/Grande Basin

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FINAL REPORT

Prepared by

The University of Texas at Austin

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Abstract

The Center for Research in Water Resources (CRWR) of the University of Texas at Austin in cooperation with the National Water Commission of Mexico (CNA) and the support of the North American Development Bank (NADBANK) has developed a binational dataset to build hydrologic information systems, which can be used to support hydrologic analysis and modeling in the Rio Grande/Bravo basin. This dataset consists of an ArcHydro-based Geographic Information System and relational data base containing hydrologic and hydraulic information from the United States and Mexican sides. It will assist in developing bi-national cooperation between Mexico and the United States concerning water in this basin, providing accurate and reliable data necessary for analysis and resolution of water resources issues. Information collected in the project from both Mexican and U.S. agencies did not have the same features and presented some errors, especially in the river system dataset. This information has been processed and reprojected in order to use the same characteristics for the whole basin, creating several classes of data features (feature classes) contained in a geographically referenced database (i.e., a geodatabase). The concept of regionalization was introduced in order to divide the basin into several hydrological subregions, so gridcell-based (or raster) data sets were decomposed into smaller, more manageable sizes to avoid computer memory and processing time difficulties when the geodatabase was developed. This geodatabase represents the first major attempt to establish a more complete understanding of the basin as a whole, using both Mexican and U.S. data.

Contents

1. Introduction

The Rio Grande/Bravo is a transboundary water source shared by the United States and Mexico. At this time, Mexico is in the process of improving its ability to develop and implement efficient management plans for the water in the Rio Grande/Bravo basin, taking into account the new developments in Mexican water law and the existing infrastructure and methods of application and distribution of water. A continually increasing population, serious problems related to lack of sanitation and clean water, as well as regular high investments in infrastructures which are not achieving their objectives, are likely to force governments at various levels to search for alternative approaches, other than relying only on engineering solutions through supply management alone. The institutions concerned are aware that successful water resources management requires a long term planning process from technical, economic, political, social, and environmental viewpoints.

In addition, some decisions about water management are only partially supported, causing alterations in the global ecosystem. For this reason it is necessary to improve the administration and management of water in this watershed. This requires an assessment of water availability and the means to manage it appropriately for agriculture, industry and other services, also taking into account ecosystem preservation.

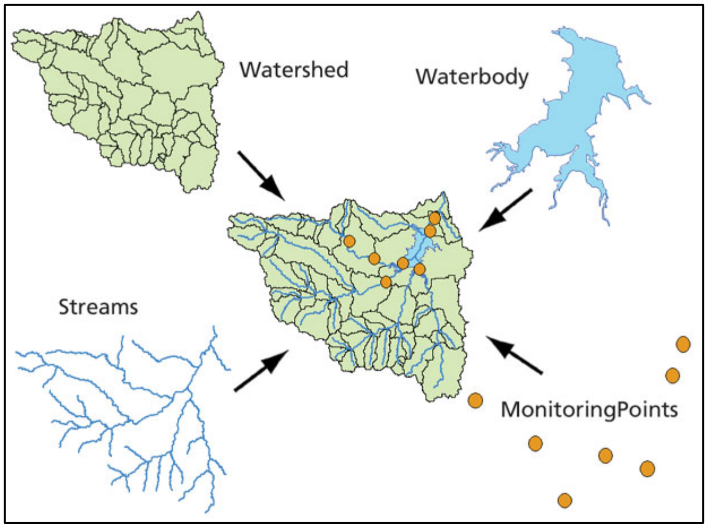
Recent drought conditions have increased tensions over water sharing in the Rio Grande basin. Several areas of conflict and possible negotiated remedies have been identified, but there is a lack of data available to use in analysis of alternative solutions to these problems.

The development of a watershed-scale database for the Rio Grande/Bravo basin is of critical importance. Minute 308 of the International Boundary Waters Commission (IBWC), June 28, 2002, states that it is very important to support projects that increase data exchange related to the management of hydrological information systems. These systems should include information from both sides of the basin in a timely manner to enable the IBWC to adopt principles and understandings under which both Governments provide the highest priority to fulfilling their respective obligations under the 1944 Water Treaty.

In this research project, the Center for Research in Water Resources (CRWR) of the University of Texas at Austin, the Mexican Institute of Water Technology (IMTA), the National

Water Commission (CNA) of Mexico, with support from the Texas Commission on Environmental Quality (TCEQ) and the North American Development Bank (NADBANK), have cooperated to develop the relational database containing geographic, hydrologic, hydraulic and related data for the basin, as shown in figure 1. This geographically referenced database was created using the ArcHydro data model (Maidment, 2002) for the entire Rio Grande/Bravo basin.

Figure 1. Relational integration of thematic layers in the ArcHydro data model (Maidment, 2002)



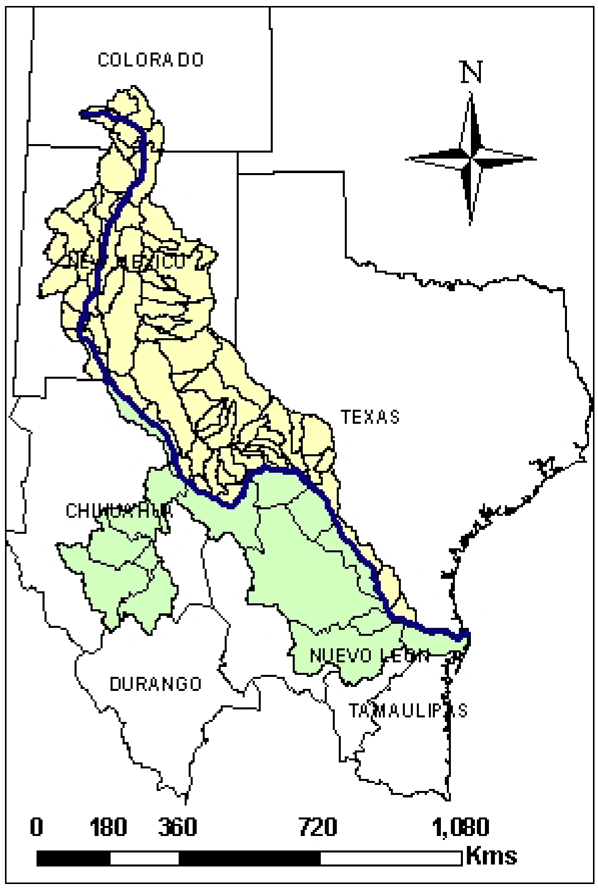
1.1 Study Area

The Rio Grande originates in the San Juan Mountains of southern Colorado. Flowing 858 kilometers from its headwaters and through the state of New Mexico, it enters Texas about 12 kilometers northwest of El Paso and then continues 2034 kilometers to the Gulf of Mexico (Patino et al, 2004). Figure 2 shows the total length of the river, as well as the political division of the Rio Grande/Bravo basin that includes the Hydrologic Unit Cataloging (HUCs) on the U.S. side and Cuencas and sub-Cuencas on the Mexican side.

The Rio Grande is the fifth longest river in North America (2895 Km), and among the 20 longest rivers in the world. The river carries little water compared to other rivers of its length. For this reason, it has been classified by the Encyclopedia of Water in the West (2002) as an exotic stream, which means that it tends to shrink in size as it flows downstream. This is typical of rivers that pass through arid regions. Most precipitation in the basin falls at either end of the river, as snow near its headwaters or as rain near its mouth.

The river collects rain, snowmelt and spring water from an area about 557,722 square kilometers including closed basins. The whole basin includes three states on the U.S. side (Colorado, New Mexico, and Texas), and five states on the Mexican side (Chihuahua, Coahuila, Durango, Nuevo Leon, and Tamaulipas). From the basin area, 225,380 Km^2 lies on the Mexican side and 242,994 Km^2 on the U.S. side, without considering closed basins.

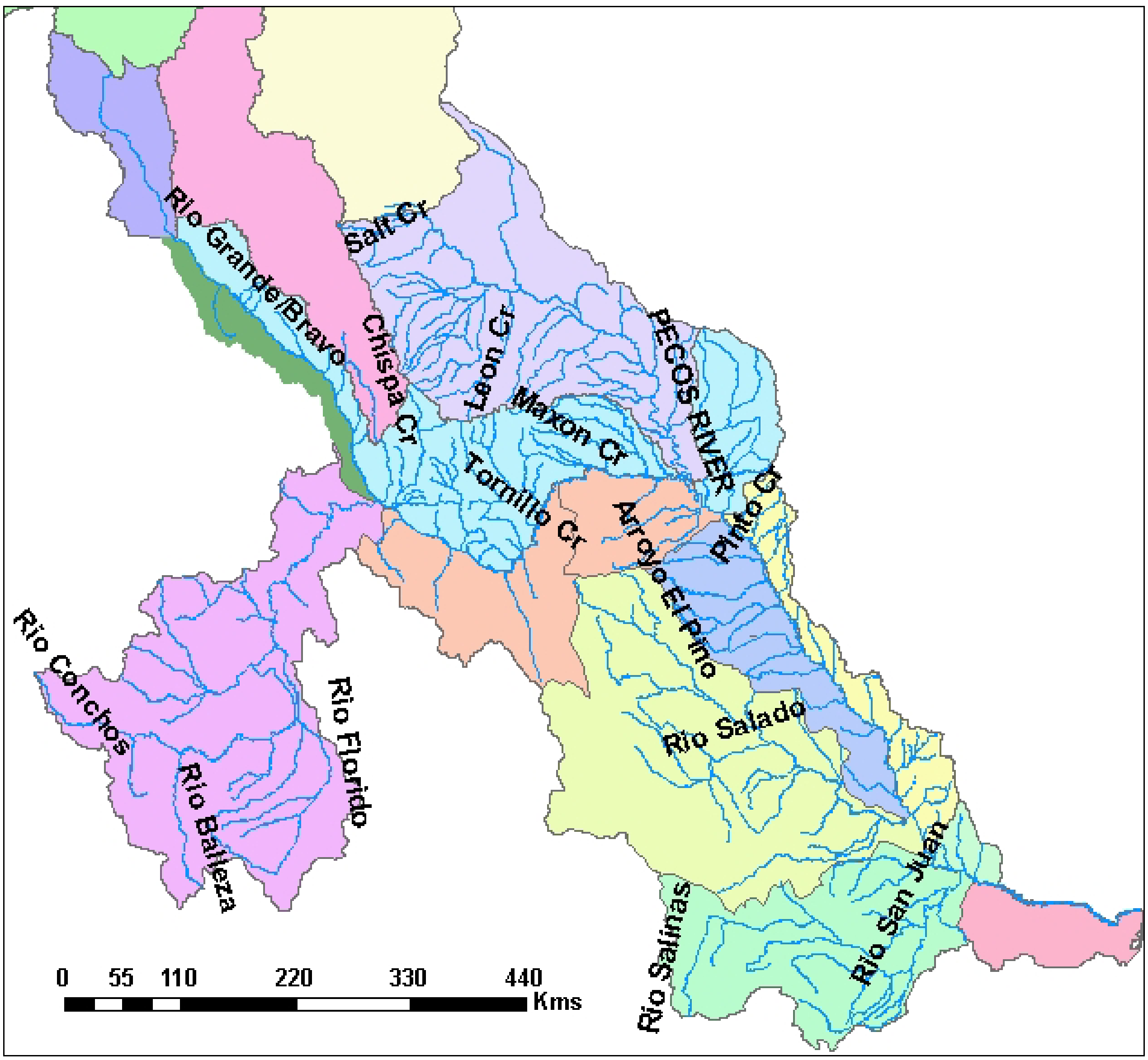
Fig. 2. Political division of the Rio Grande/Bravo basin



The basin is divided in two sub basins, the Upper Rio Grande Basin that includes Colorado, New Mexico, and part of Texas, and the Lower Rio Grande Basin (LRGB) that includes parts of the state of Chihuahua, Durango, Coahuila, Nuevo Leon, Tamaulipas, and Texas. The LRGB, from Fort Quitman to the Gulf of Mexico , including the Rio Conchos and Pecos sub-basins, is the case study area for this project. This area encompasses the drainage of all major tributaries downstream of El Paso and Ciudad Juarez. The portion of the basin that lies in this study area is known in Mexico as the Cuencas Del Rio Bravo del Norte.

A part of the Rio Grande basin lies within North America's largest desert, the Chihuahua Desert. Mexico irrigates about 1.1 million acres in the basin, while the United States irrigates about 993,000 acres. Only 98,000 acres of irrigated land in the Rio Grande basin lie upstream from Texas (The Alliance for the Rio Grande Heritage et al, 2000). The Conchos, San Pedro, San Rodrigo, Alamos, and San Juan Rivers are the primary tributaries in Mexico. The Pecos and Devil Rivers are the principal tributaries to the river in Texas (Figure 3).

Figure 3. The primary tributaries in the Rio Grande/Bravo basin



The Rio Grande/Bravo basin is considered an arid to semi-arid region, dominated by agriculture and with limited supplies of both surface and groundwater. Average rainfall in the basin ranges from 200 – 900 millimeters with the highest values in the upper basin of the Rio Conchos (Patino et al, 2004). The Rio Conchos enters to the Rio Grande/Bravo near Presidio, Texas, just upstream of Big Bend National Park and Ojinaga, Mexico; in a region of mountains and canyons. The basin ranges from arid and suitable for crops, to semi-arid and hospitable to some crops only. Along the entire river, water lost through evaporation exceeds water gained from precipitation. The Lower Valley serves as temporary or permanent home for hundreds of bird species, and the river contributes vital fresh water to its gulf estuary (Tate, 2002).

1.2 Data Collection

Hydrological information was obtained from Mexican and U.S. agencies for the project. The political boundaries, river network, water bodies and gauging stations on the Mexican side were collected from the National Water Commission (CNA), the Mexican Institute of Water Technology (IMTA), the University of Ciudad Juarez (UACJ), the Comision Internacional de Limites y Aguas (CILA), and the National Institute of Geography and Information (INEGI). The information for the U.S. side was obtained from the U.S. Geological Survey (USGS), the Texas Commission on Environmental Quality (TCEQ), the International Boundary Water Commission (IBWC), and the Texas Natural Resources Information System (TNRIS), among others agencies. The data collected from the original sources are listed in table 1, as well as some of the data characteristics.

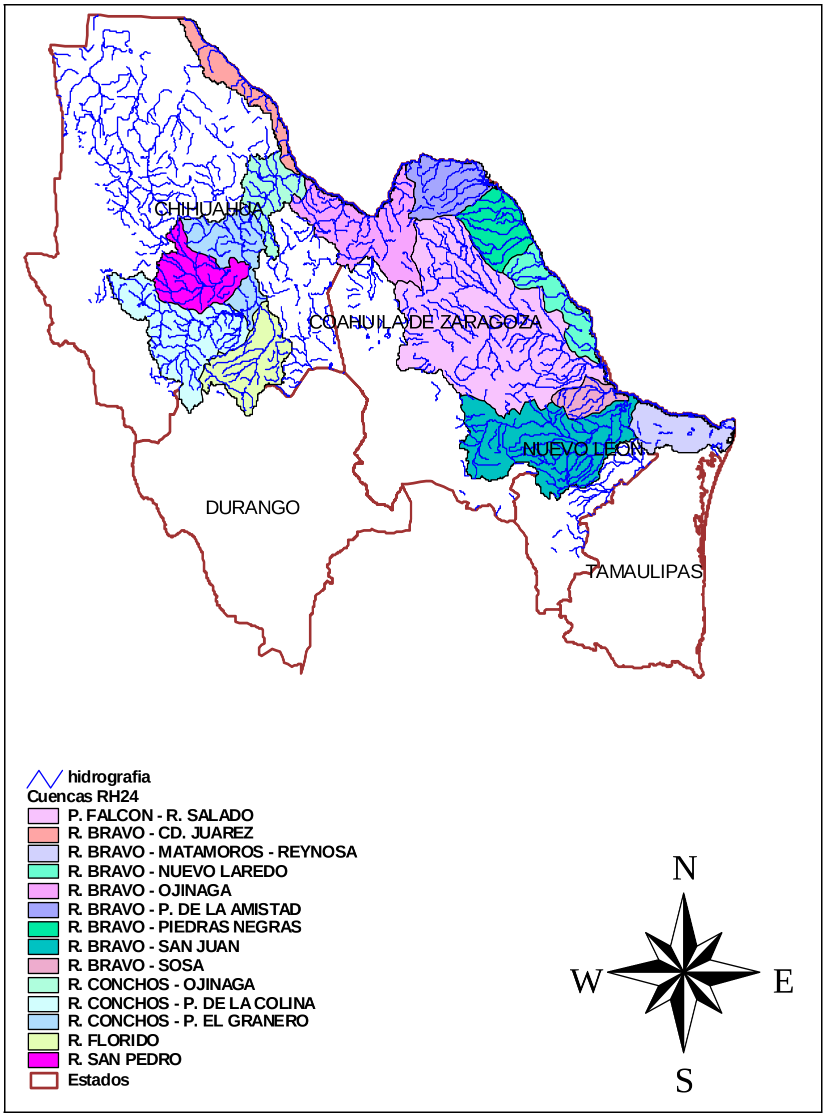
Errors were found in some of the hydrological information, including incorrect positions of some monitoring and control points, disconnected river reaches, incorrect locations of some water bodies, etc. Part of the original information is shown in Figure 4. This information had to be edited in order to fix these errors.

The Mexican agencies usually use the Geographic Coordinate System and Lambert geographic projection to create their geographic information. The Albers equal area projection was proposed for this project in order to preserve the areas. The Datum chosen was the NAD Datum 1983; the Geographic Coordinate System corresponds to GCS_North_American_1983, while the Central Meridian is located at -103 degrees, near the center of the basin.

Table 1.Summary of the original data collected for the Rio Grande/Bravo basin

Description of data	Mexico	USA
Political boundaries (States included in the Rio Grande basin). Source: U.S. Department of Transportation. Scale: 1:250K	Available	Available
Basin Delineation. Source: USGS-HUC for the U.S. side (1:100K) Cuencas and Sub-Cuencas from IMTA and UACJ for the Mexican side (1:250K)	Available	Available
Hydrography (Stream network). Source: USGS for U.S. (Scale 1:100K). Mexican Institute of Water Technology (IMTA), National Water Commission (CNA), INEGI, and University of Ciudad Juarez (UACJ) for the Mexican side (Scale 1:250 K).	Available	Available
Water Bodies and dam locations. Source: USGS- HUC'S for the U.S. side (1: 100K). IMTA, CNA, INEGI, and UACJ for the Mexican side (1:250K)	Available	Available
Monitoring point's location. Source: USGS, TCEQ, and IBWC for the U.S. side. IMTA, CNA, and CILA for the Mexican side as hydrometric and climatic stations.	Available	Available
Historical hydrometric information (time series). Sources: National Water Information System (NWIS) and the IBWC for the U.S. side (1940 – 2000). IMTA, CNA, and CILA for the Mexican side. Part of this information is included in the BANDAS software developed by the CNA that includes 67 hydrometric stations located in the Rio Grande/Bravo basin	Available	Available
Climatologic information (time series). Sources: USGS and PRISM for the U.S. side IMTA and CNA for the Mexican side. This information is included in the ERIC System (230 climatic stations on the Mexican side operating until 2002.)	Available	Available
Digital Elevation Model (DEM). Source (Seamless format): USGS for the U.S. side. Resolution: 30 m of cell size. Source on the Mexican side: INEGI. Cell size: 104 m	Available	Available
Control Points (Include water rights, return flow points, diversions, etc) This information was obtained from the TCEQ on the U.S. side; and from the CNA for the Mexican side. This information was available as a shapefile in ArcView 3.2	Available	Available

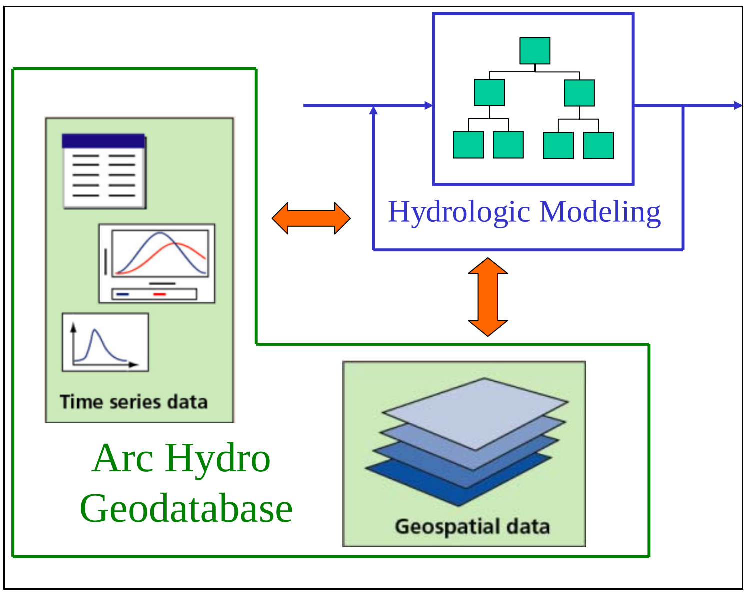
Figure 4. Cuencas, Sub Cuencas and original hydrography of the Rio Bravo basin on the Mexican side



2. Developing the Geodatabase

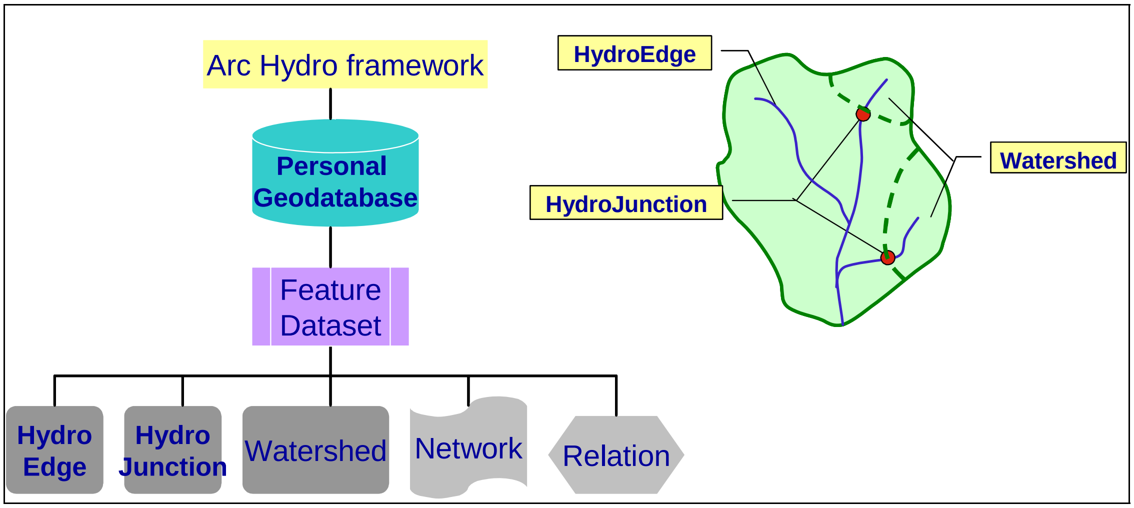
The development of a watershed-scale database is fundamental to analyzing water resource management problems in the Rio Grande/Bravo basin. Even though separate research efforts have been carried out on each side of the river, an integral database has not been created previously that includes data from both sides of the basin. As in many watersheds, knowledge and information available about the Rio Grande/Bravo basin is fragmented, disjointed, incomplete, and sometimes inaccurate. Integrated management of a river basin requires the development of models that are used for many purposes, e.g., to assess risks and possible mitigation of droughts and floods, manage water rights, assess water quality, and simply to understand the hydrology of the basin. For this purpose a database is needed from which models can access the various data needed to describe the systems being modeled (figure 5). In other words, a database from which models read input data and to which they write output data. In order for this concept to work, however, it must have a standard design. The recently developed ArcHydro data model facilitates access to hydrologic information by models (Maidment, 2002).

Figure 5. Hydrologic Information System (Maidment, 2002)



Creating an ArcHydro geospatial database for the entire Rio Grande/Rio Bravo basin represents the first major attempt to establish a more complete understanding of the basin as a whole, using both Mexican and U.S. geospatial and temporal data for water resources. It is possible to obtain from the database information about climatology, water availability, water uses, hydraulic infrastructure, and drainage in the basin that are included as feature classes within the relational database (Figure 6). These data will permit models to calculate the state of water availability under different climatic and development scenarios and management plans in the future.

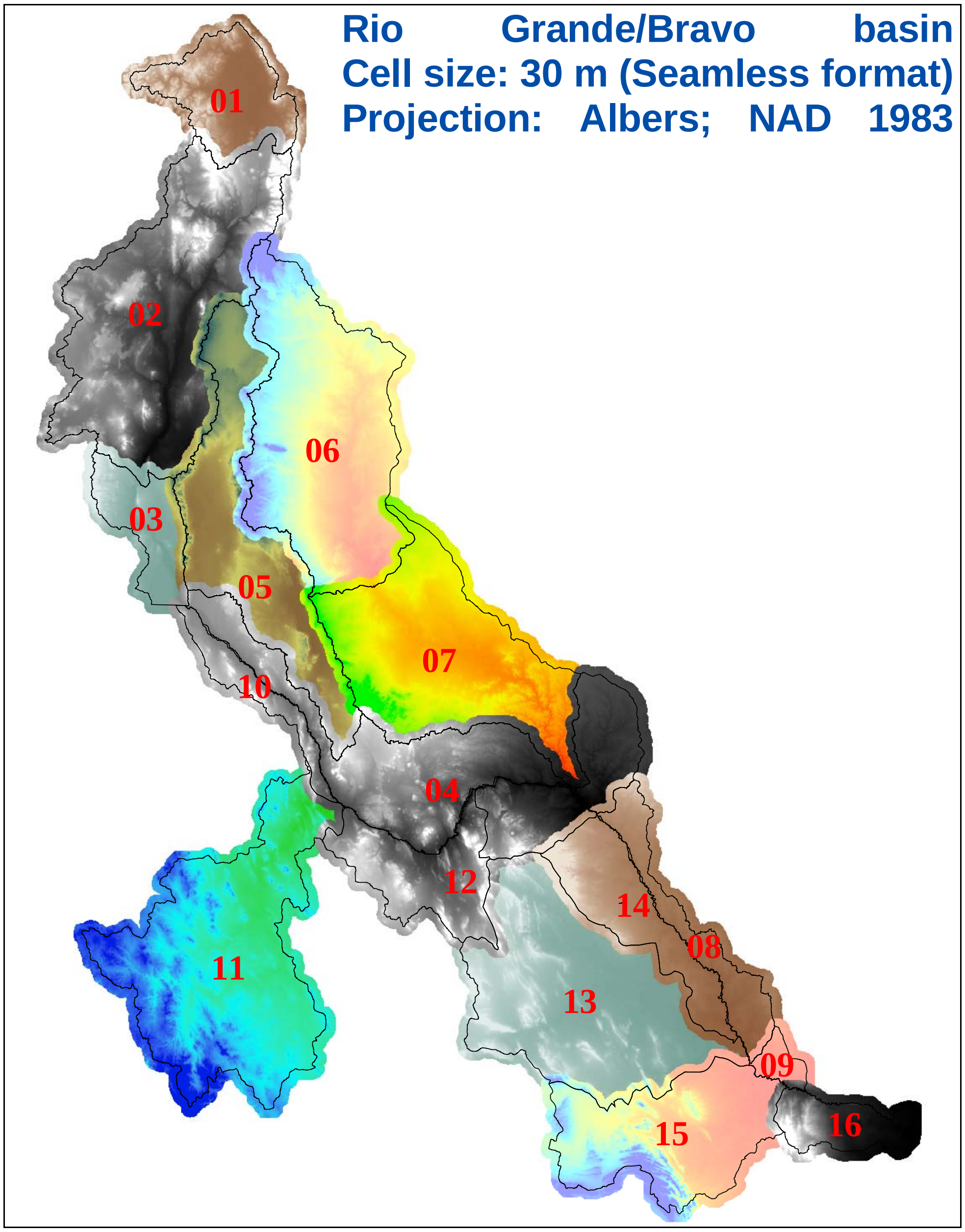
Figure 6. ArcHydro data model for water resources



2.1 Clipping and Merging Data Sets

In constructing the geodatabase for the Rio Grande/Bravo basin, data distributed on a national or state level had to be clipped to remove information outside the study area; while data distributed at a county or Hydrologic Cataloging Unit level, had to be merged into a single and larger data set. Because the original DEM for Mexico existed for the whole country with a grid size of 104 m, it had to be clipped and resampled on a 30 m grid (to make it compatible with the resolution of the data on the U.S. side) based on the basin boundaries. With respect to the USGS DEM for the U.S. side, the original seamless tiles are projected using the GCS_1983 and a grid resolution of 28.3 m; so they had to be reprojected and resampled to match the projection and characteristics chosen for the project. The result of this step is shown in Figure 7.

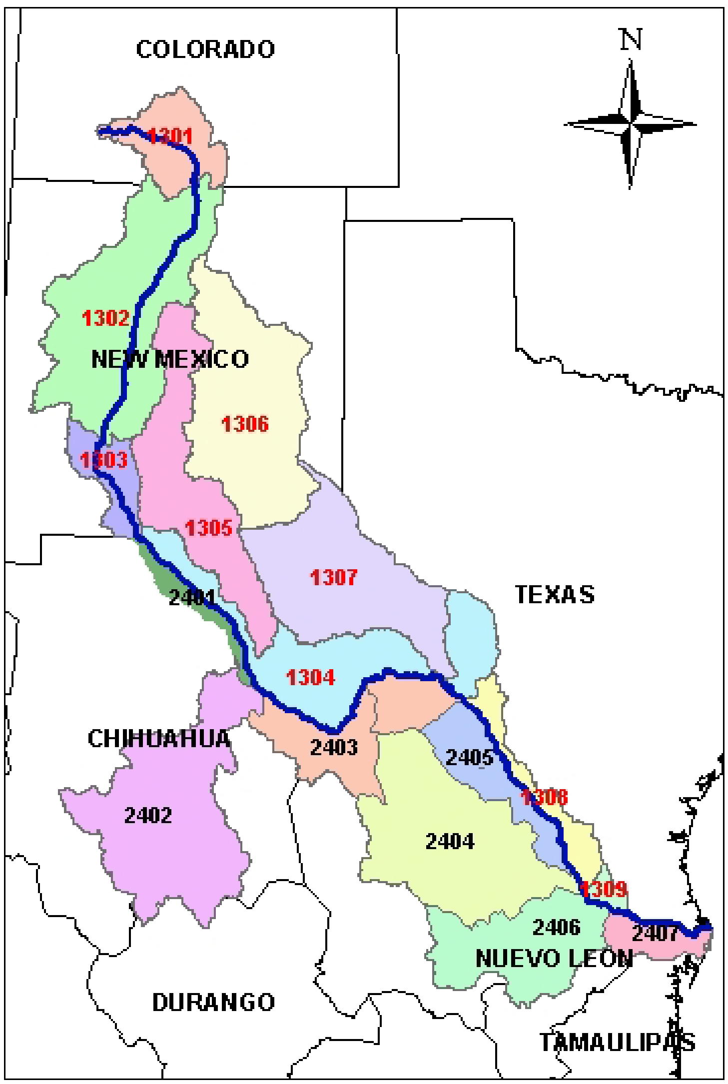
Figure 7. Clipped DEMs for the basin including a 10 Km buffer



2.2 Creating Feature Datasets

This step consisted of entering and processing the available information into the ArcHydro Rio Grande/Bravo geodatabase. Several feature datasets (essentially, sets of data with specific characteristics in the geodatabase) were created that include feature classes (layers of data within the feature datasets) related to each type of information. When working with huge basins like the Rio Grande/Bravo basin, the computer processor is not be able to handle the large raster datasets. This is handled by dividing the basin into sub-regions and processing the rasters individually for each sub-region. Then the values obtained for each sub-region can be cascaded downstream to get the final parameters for the entire basin. For this reason, the whole basin was divided into 9 hydrological subregions on the U.S. side, according to the USGS classification, and 7 hydrological subregions on the Mexican side, in order to apply the ArcHydro process subregion by subregion (Figure 8).

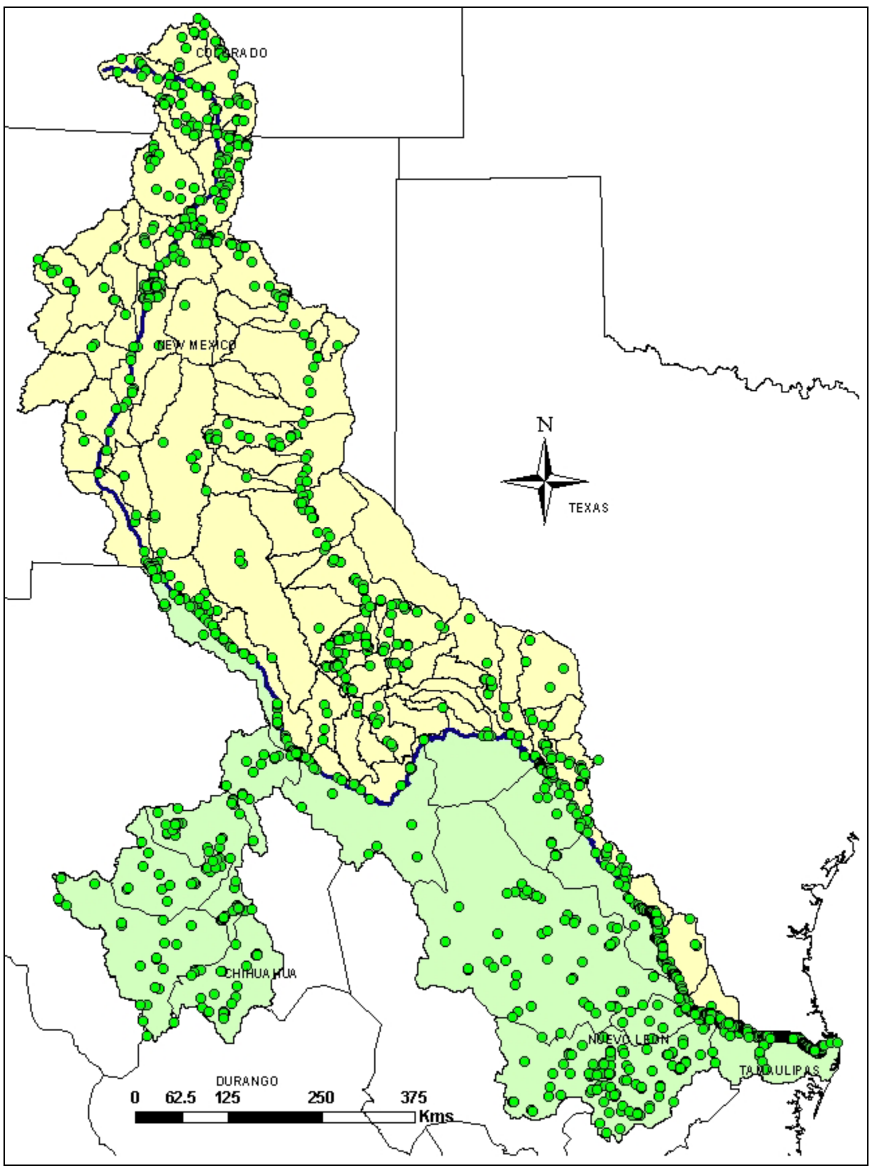
Figure 8. Hydrological subregions of the Rio Grande/Bravo basin



2.3 Obtaining Time Series Data

Climatic and hydrological time series data corresponding to monitoring points located in the Rio Grande/Bravo basin were collected and imported from the BANDAS and ERIC databases in Mexico, and NWIS database in the U.S. Average annual precipitation was obtained from 230 climatic stations located on the Mexican side. Around 2100 locations (control points) including water rights, hydrometric stations, water diversions, return flow points, etc., were identified in the whole basin (Fig. 9)

Figure 9. Control Points identified in the Rio Grande/Bravo basin



The ArcGIS format was applied to all the time series data in order to include them in the geodatabase and relate them to the monitoring and control points. The ArcHydro Time Series format was changed, adding a new table called TSGroup that contains information related to the agency from which data are derived. Two tables describing the agencies and variables included in the Geodatabase are shown below.

Table 2. Variables Included in the Geodatabase

Attributes of TSType

OBJECTID*	TSTypeID*	Variable	Units	IsRegular	TSInterval	DataType	Origin
1	1	Daily Streamflow	cms	True	1Day	Average	Recorde
2	2	Monthly Streamflow	cms	True	1Month	Cumulative	Recorde
3	3	Real Time Streamflow	cms	True	15Minute	Instantaneous	Recorde
4	4	Stage	m	True	1Day	Average	Recorde
5	5	Daily Runoff Volume	Million of m3	True	1Day	Average	Generate
6	6	Monthly Runoff Volume	Million of m3	True	1Month	Cumulative	Generate
7	7	Daily Precipitation	mm	True	1Day	Cumulative	Recorde
8	8	Monthly Precipitation	mm	True	1Month	Cumulative	Generate
9	9	Monthly Evaporation	mm	True	1Month	Cumulative	Recorde
10	10	Monthly Storage Volume	Million of m3	True	1Month	Average	Recorde
11	11	Irrigat_District_Volum_Demand	Million of m3	True	Other	Cumulative	Recorde
12	12	Inflow Monthly Volume	Million of m3	True	1Month	Cumulative	Recorde
13	13	Outflow Monthly Volume	Million of m3	True	1Month	Cumulative	Recorde
14	14	Daily Storage Volume	Million of m3	True	1Day	Average	Recorde

Record: 1 Show: All Selected Records (0 out of 14 Selected.) Options

Table 3. Agencies Participating to Create the Geodatabase

Attributes of TSGroup

OBJECTID	FeatureID	Agency	GroupID*
1	1	CNA	1
2	2	IBWC	2
3	3	IMTA-BANDAS&SICLIM	3
4	4	USGS	4
5	5	TCEQ	5
6	6	CILA	6
7	7	Other	7

Record: 1 Show: All Selected Records (0 out of 7 Selected.)

Users can select a specific monitoring point within the geodatabase and several relationships have been established for it, so they can identify the agencies from which the temporal data was derived, as well as the type of variable. The Rio Conchos runoff to the Rio Grande/Bravo is shown in Table 4

Table 4. Monthly Runoff at the Gage Station Rio Conchos-Ojinaga

Selected Attributes of MonitoringPoint

OBJECTID	Shape*	CRWR_ID	HydroID*	NAME
1799	Point	08-3730.00	1040700007	Rio Conchos at Ojinaga (FM1000), Water delivers from Conchos to Rio Bravo/Grande (Total allocation)

Record: 1 Show: All Selected Records (1 out of *2000 Selected.) Options

Selected Attributes of TimeSeries

OBJECTID*	FeatureID*	TSTypeID*	TSDateTime	TSValue	GroupID*
157844	1040700007	6	9/30/2000	5.915	6
157845	1040700007	6	10/31/2000	22.538	6
157846	1040700007	6	11/30/2000	5.493	6
157847	1040700007	6	12/31/2000	17.783	6
157848	1040700007	6	1/31/2001	46.276	6
157849	1040700007	6	2/28/2001	24.444	6
157850	1040700007	6	3/31/2001	4.692	6
157851	1040700007	6	4/30/2001	5.413	6
157852	1040700007	6	5/31/2001	6.452	6
157853	1040700007	6	6/30/2001	5.402	6
157854	1040700007	6	7/31/2001	10.41	6
157855	1040700007	6	8/31/2001	14.841	6
157856	1040700007	6	9/30/2001	4.515	6
157857	1040700007	6	10/31/2001	2.564	6
157858	1040700007	6	11/30/2001	0.758	6

Record: 1 Show: All Selected Records (408 out of *2000 Selected.) Options

Attributes of TSType

OBJECTID*	TSTypeID*	Variable	Units	IsRegular	TSIn
1	1	Daily Streamflow	cms	True	
2	2	Monthly Streamflow	cms	True	
3	3	Real Time Streamflow	cms	True	
4	4	Stage	m	True	
5	5	Daily Runoff Volume	Million of m3	True	
6	6	Monthly Runoff Volume	Million of m3	True	
7	7	Daily Precipitation	mm	True	
8	8	Monthly Precipitation	mm	True	
9	9	Monthly Evaporation	mm	True	
10	10	Monthly Storage Volume	Million of m3	True	
11	11	Irrigat_District_Volum_Demand	Million of m3	True	
12	12	Inflow Monthly Volume	Million of m3	True	
13	13	Outflow Monthly Volume	Million of m3	True	

Record: 1 Show: All Selected Records (1 out of 14 Selected.) Options

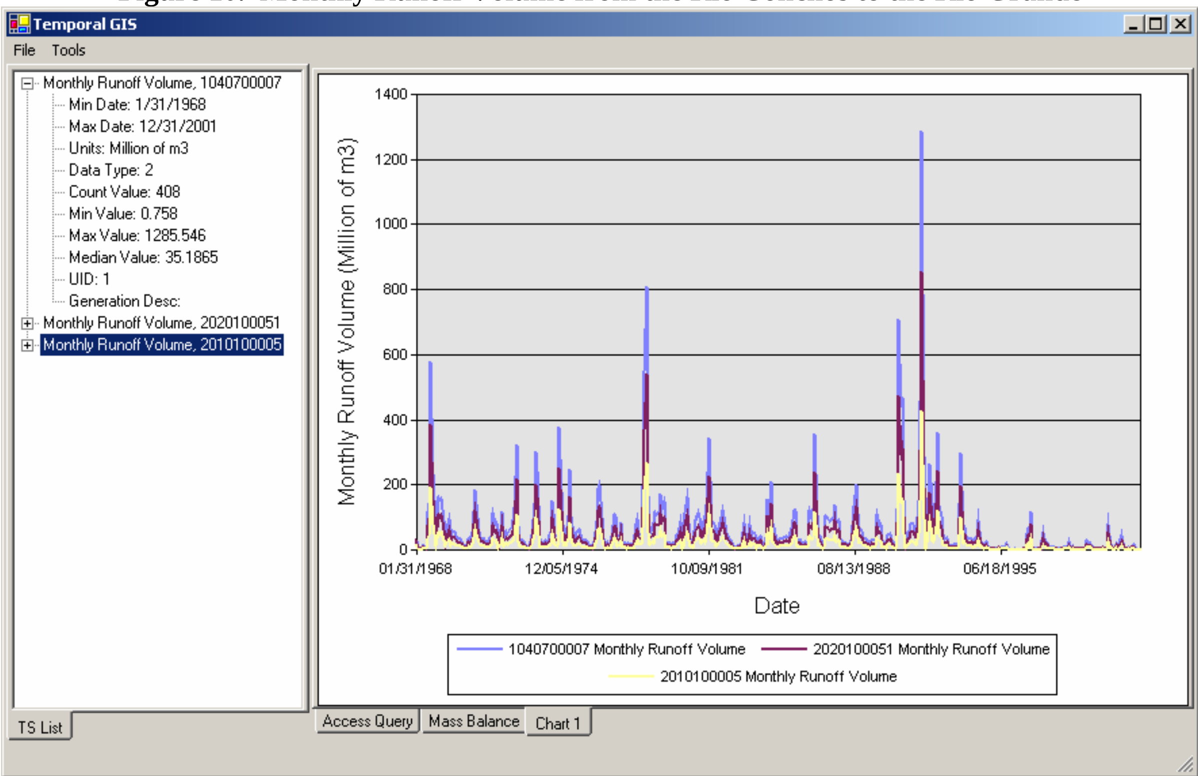
Attributes of TSGroup

OBJECTID	FeatureID	Agency	GroupID*
1	1	CNA	1
2	2	IBWC	2
3	3	IMTA-BANDAS&SICLIM	3
4	4	USGS	4
5	5	TCEQ	5
6	6	CILA	6
7	7	Other	7

Record: 1 Show: All Selected Records (1 out of 7 Selected.)

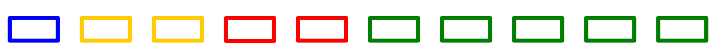
Also, a time series viewer developed at CRWR was applied in order to plot the behavior of the temporal information (Goodall, 2004). The information related to runoff from the Rio Conchos to the Rio Grande/Bravo is shown in Figure 10; where you can see the total discharge to the Rio Grande identified by the identification number (HydroID) 1040700007. The regional HydroIDs 2020100051 and 2010100005 correspond to the discharge to the Rio Grande from Mexico and the U.S. respectively.

Figure 10. Monthly Runoff Volume from the Rio Conchos to the Rio Grande



2.4 Applying Regional HydroIDs

A unique ten-digit identification number called the "Regional HydroID" was assigned to every feature class according to the following classification:



The first digit (from left to right) indicates the hydrological region (blue box). Region 13 on the U.S. side was identified with the number 1, and number 2 identified region 24 on the Mexican side. The second 2 digits (yellow boxes) describe the Hydrologic SubRegion. The basin is divided into 9 subregions on the U.S. side and 7 subregions on the Mexican side. The next two digits (red boxes) correspond to the feature class. The value 01 was assigned for the ControlPoint feature class, while the value 02 was assigned for edges (River network). The waterbody feature class was identified as 03, Watershed as 04; and so on. The last five digits (green boxes) describe the feature number, with a maximum of 99,999 values. The Regional HydroID for the Rio

Conchos basin is shown in Table 5 as an example.

Table 5. Regional HydroID for the Rio Conchos Basin with original Mexican Code preserved.

Attributes of Watershed

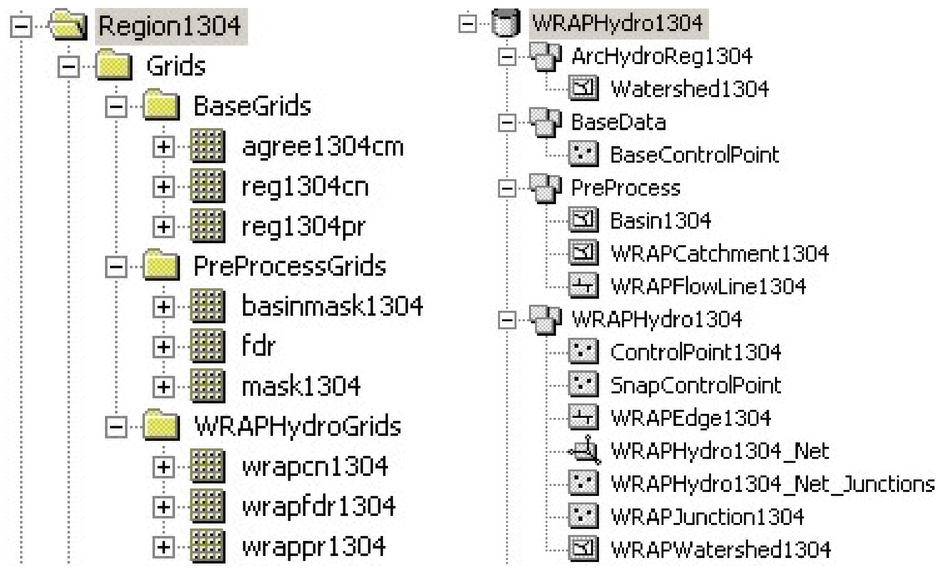
NAME	MEX_CODE	HydroID
R. CONCHOS - OJINAGA	24-J	2020400001
R. CONCHOS - P. EL GRANERO	24-K	2020400002
R. SAN PEDRO	24-N	2020400003
R. CONCHOS - P. DE LA COLINA	24-L	2020400004
R. FLORIDO	24-M	2020400005

Record: 1 Show: All Selected Records (0 out of 5 Selected.)

2.5 WRAPHydro Data Model

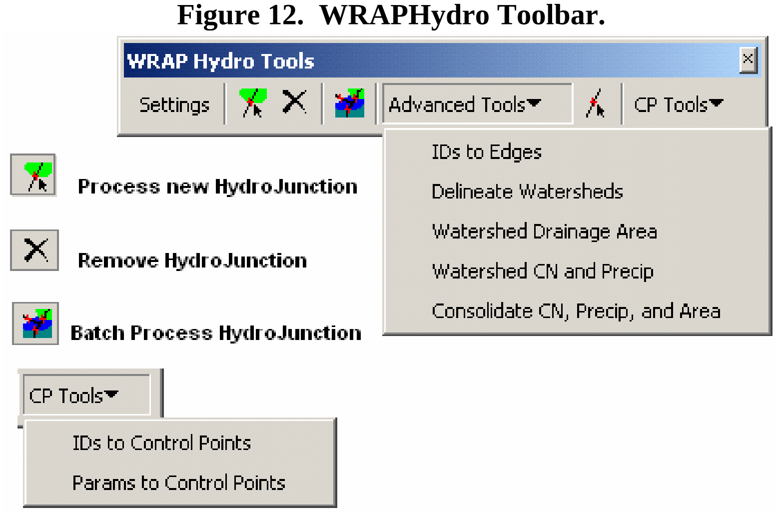
A particular application of the ArcHydro data model called WRAPHydro was applied to each of the Rio Grande/Bravo hydrological subregions in order to create the necessary fields required by the Water Right Analysis Package (WRAP) model (Wurbs, 2001). The WRAPHydro data model was derived from the ArcHydro model and is tailored specifically for the WRAP project developed jointly with the Texas Commission on Environmental Quality (TCEQ) (Gopalan, 2002). It is shown in Figure 11. The WRAP is a hydrological simulation model for evaluating existing water right permits, permit approvals for new water rights, and overall water management in Texas under a priority based water allocation system (Wurbs, 2001).

Figure. 11. Schema of the WRAPHydro Data Model.



All of the WRAPHydro data model fields were populated using the WRAPHydro tools developed at the CRWR (Whiteaker, 2004). These tools consist of a set of public domain utilities developed on top of the ArcHydro data model. The tools are accessed through the WRAPHydro toolbar, where they are grouped by functions into two menus and five buttons (Figure 12). The purpose of this toolkit is to process GIS data in order to calculate parameters used by WRAP and tabulated for each ControlPoint including: average curve number, average annual precipitation, total upstream drainage area, and next downstream Control Point.

Figure 12. WRAPHydro Toolbar.



2.6 WRAPHydro Tools

For each hydrological subregion, the HUCs or SubCuencas that make up the subregion were selected, and a geometric river network was created (the HydroNetwork), then the hydrography information had to be checked. Every stream in the network must be connected and the flow direction assigned correctly. The HydroNetwork is an essential part of this data model, created from edges (WRAPFlowlines) and control points. The topological connections of the edges and control points in a geometric network enables tracing of water movement upstream and downstream through streams, rivers, and water bodies. Relationships built from the control points connect drainage areas and point features such as diversion points to the HydroNetwork. The HydroNetwork allows calculation of the distance between any two points on a flow path. A new feature class called WRAPEdge was created from the HydroNetwork selecting all streams lying in the hydrological subregion. The total drainage area for each control point was calculated by determining the incremental watersheds that contribute to each junction, then their value was accumulated moving downstream. Watershed drainage area, average curve number and average precipitation were calculated for each watershed using the WRAPHydro tools. Once the incremental values for the drainage area, curve number and precipitation were determined for each watershed, these values were consolidated for the entire area contributing to each junction.

Figure 13 shows the result of comparing the SubCuencas of the Rio Conchos basin defined by the Instituto Nacional de Estadistica, Geografia e Informatica of Mexico (INEGI)--represented by a continuous line--and the watershed defined by the WRAPHydro Tools--represented by polygons. The connectivity among control points is shown in Figure 14. The SubCuencas were defined using a 1:250K scale topographic map, while the watersheds were calculated from a 1:100K scale WRAPEdge (from a digitized map) and a DEM grid size of 30 m. The points represent the related water rights, gage stations, and return flow control points.

Figure 13. Rio Conchos Basin Delineation

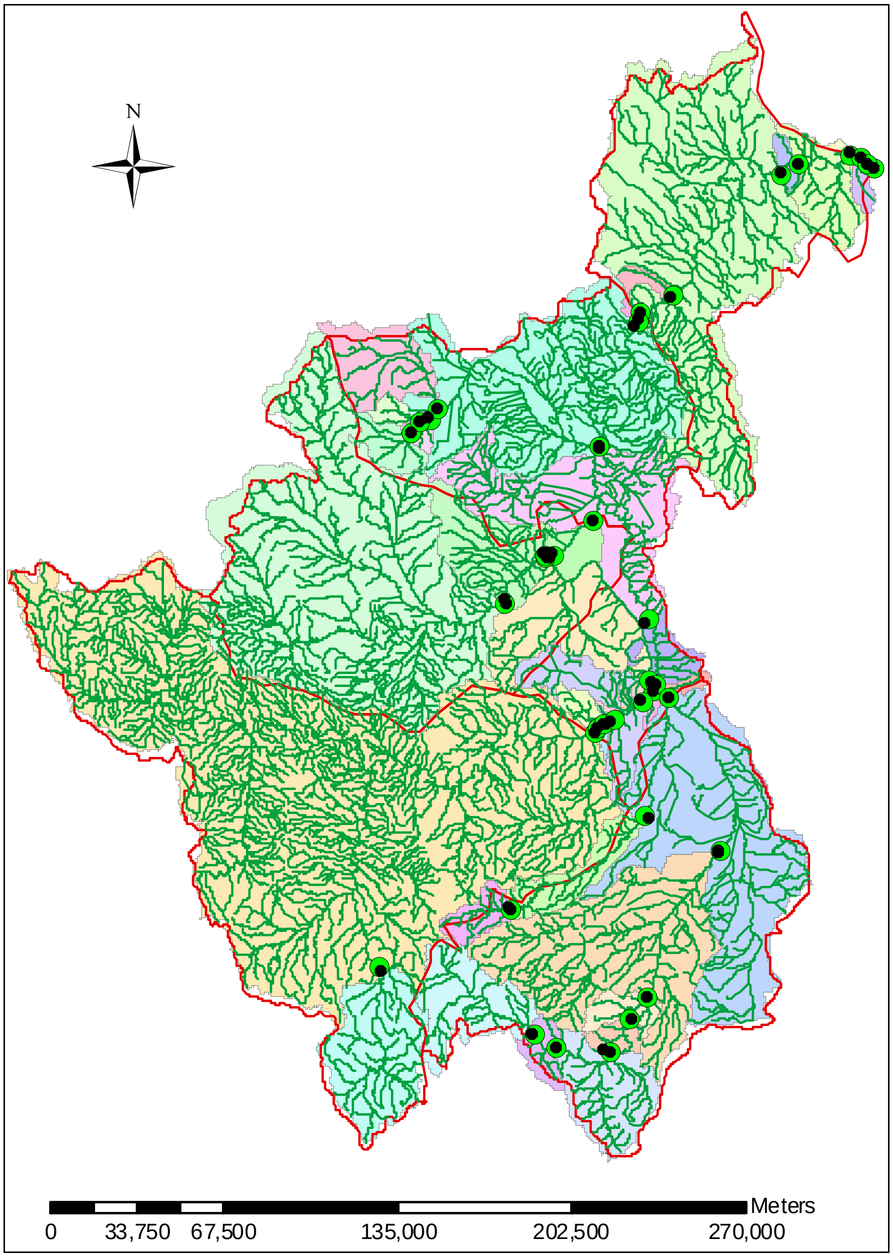
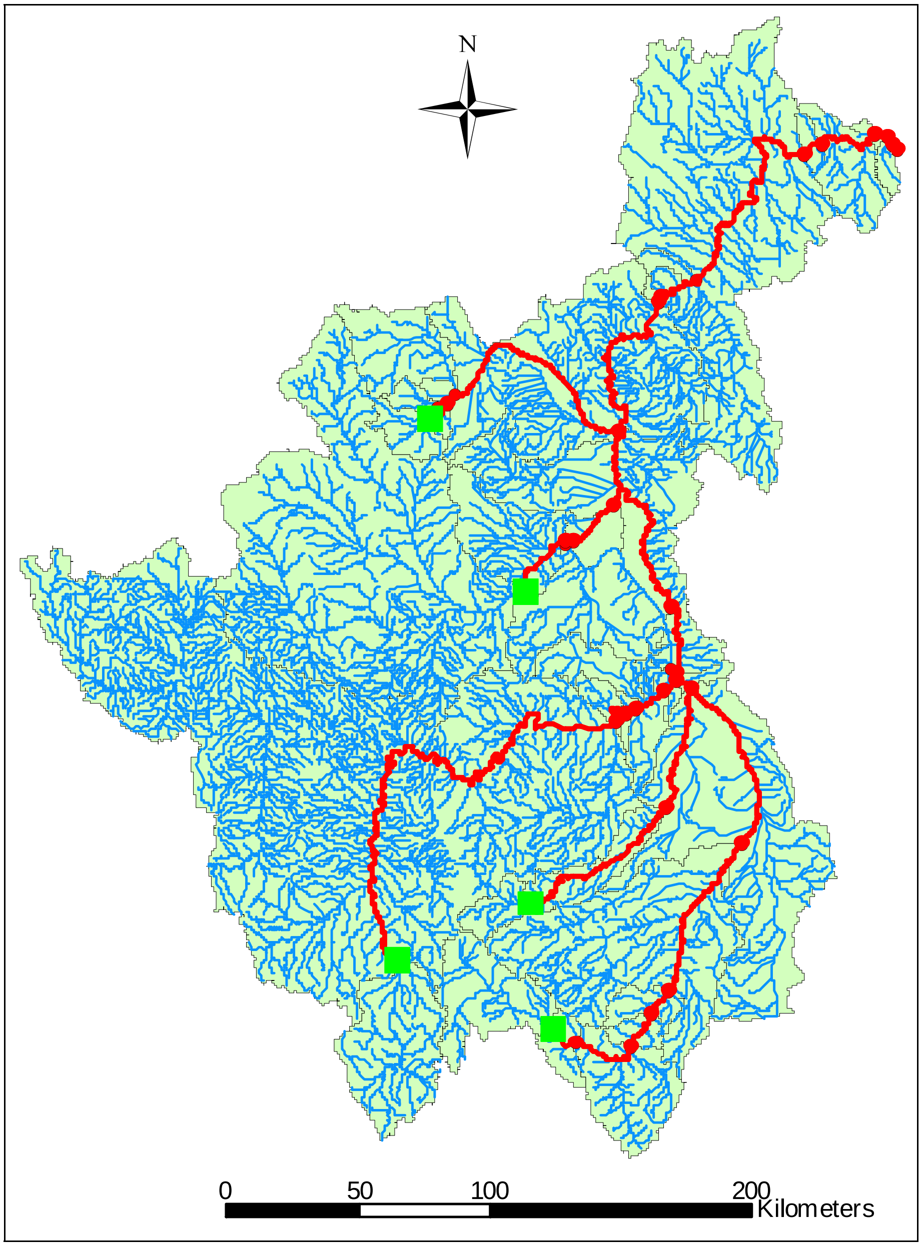


Figure 14. Rio Conchos Basin Connectivity



2.7 Regionalization Process

The research presented in this project introduces a Raster-Network Regionalization Technique, which allows a large region to be divided into distinct subregions base don hydrological characteristics where raster analyses may be performed in a feasible manner. A summation of raster values over watersheds can be easily accomplished using the watersheds as distinct zones which define the area of analysis for the zonal statistics tool in ArcGIS. Once attribute values have been determined for watersheds, these values can be transferred to outlet junctions, and then consolidated throughout the stream network in the vector domain. The watersheds become the basic processing unit with basin-wide coverage, while the raster coverage can be reduced to each individual watershed's extent. Thus, watersheds effectively replace grid cells as the "units" of analysis.

The technique was successfully applied to the Rio Grande/Bravo basin. The results from the raster analysis of each subregion were merged on the vector side to determine the total drainage area flowing toward control points, as well as their corresponding average precipitation, average curve number, and length downstream parameters. Figure 15 shows the control points and main rivers in the portion of the Rio Grande/Bravo basin from El Paso/Cd. Juarez through the Gulf of Mexico. The connectivity among the river system, junctions and watersheds is shown in Figure 16.

Figure 15. Control Points and Main Rivers in the Rio Grande/Bravo basin

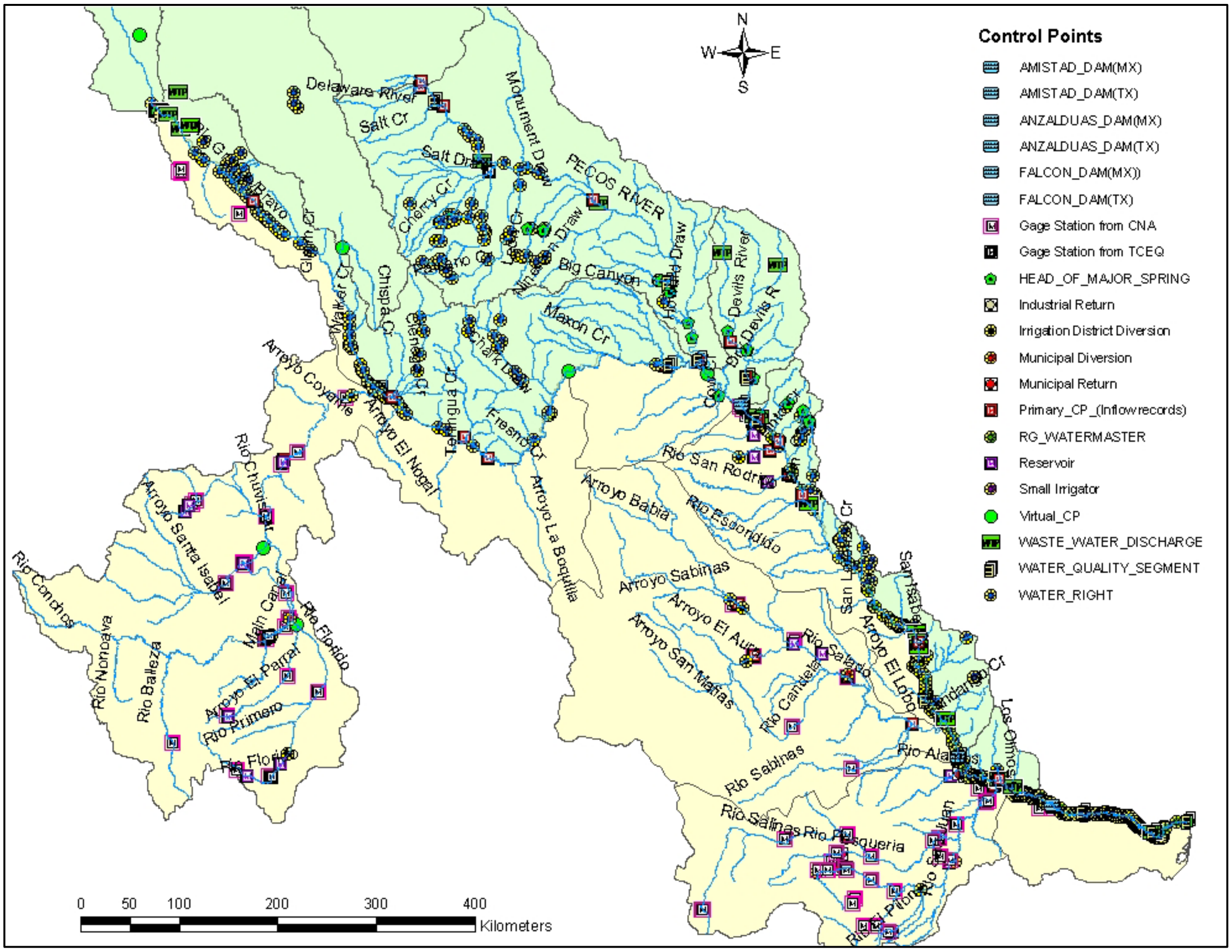


Figure 16. Connectivity in the Rio Grande/Bravo basin

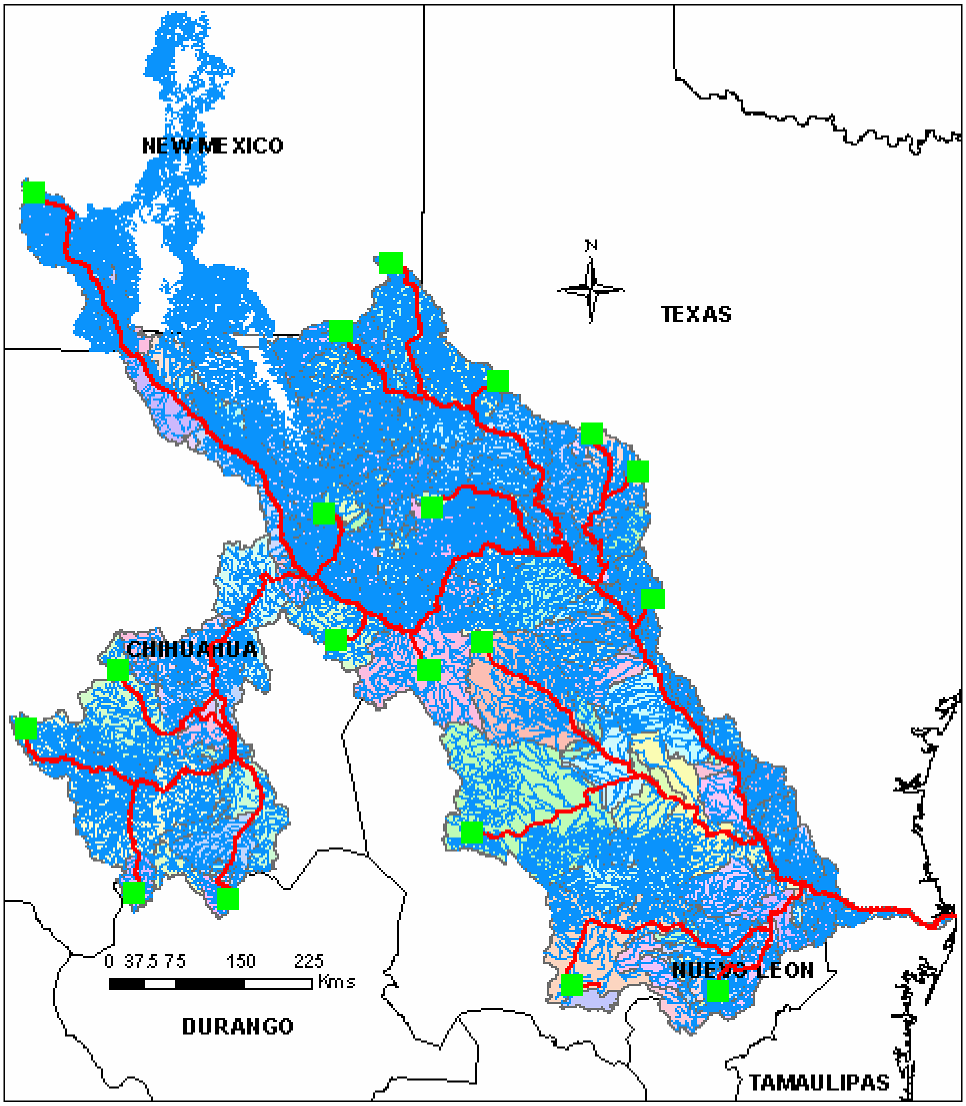
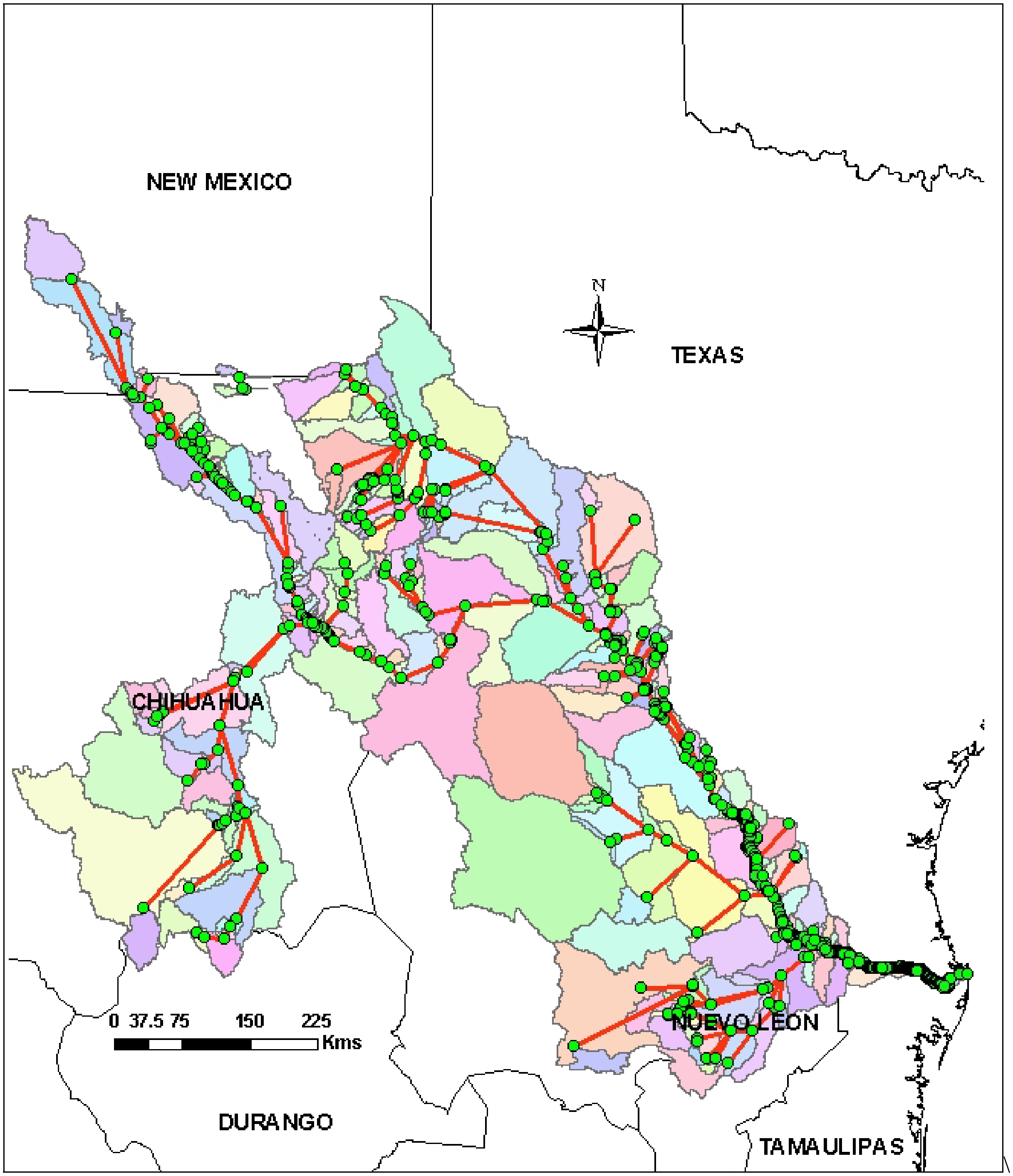


Figure 17. Schematic Network of the Rio Grande/Bravo basin



A schematic network diagram for the whole basin is shown in Figure 17. This schematic network is a simplification of the HydroNetwork that consists of separate point and line feature classes called Schematic-Node and Schematic-Link, respectively. The schematic network is an abstract representation of the elements to which hydrologic or water management models can be applied, and it provides a simplified view of the connectivity of the river network and the control points. This kind of network is useful as a visual check to make sure that the hydrologic elements needed for a model are correctly linked in the landscape (Maidment, 2002)

3. Conclusions

All completed task for this project are listed below:

- **Binational Geodatabase created**
- **Training and implementation - US counterparts**
    - 28-30 January 2004 – TCEQ Training Course and consultation
    - 2 April 2004 – USGS Consultation
    - Geodatabase delivered and installed in the TCEQ and USGS
    - 14 April 2004 – IBWC Consultation
    - Geodatabase delivered and installed in the IBWC
    - IBWC considering adopting the geodatabase
- **Training and implementation - Mexican counterparts**
    - 8-9 March 2004 – Meeting with the CNA and CILA personnel in Mexico City
    - CNA adopting the geodatabase, CILA considering adopting
    - Geodatabase delivered and installed in CNA
    - 10 March 2004 – Meeting in the IMTA
    - Geodatabase delivered and installed in the IMTA
    - 2 April 2004 – INEGI Presentation in the CRWR-UT at Austin
    - Geodatabase delivered to INEGI
    - 19-23 July 2004 – CNA Training Course and Consultation in Mexico City

A binational geodatabase was created for the Rio Grande/Bravo basin that includes a relational database containing hydrologic, hydraulic and related data. This geodatabase is being made available to Mexican and U.S. federal, state, and local organizations. It is a tool that can assist in promoting bi-national cooperation between Mexico and the United States concerning water in the Rio Grande basin, providing accurate and reliable data necessary for analysis and resolution of water resources issues. The first part of this project was to collect the hydrologic information from both Mexican and American agencies. This information did not have the same characteristics and accuracy in both sides, so it had to be edited, reprojected, and fixed in order to get unified criteria for the geodatabase.

One of the most important contributions of this research is the application of a Raster-Network Regionalization technique, which utilizes raster-based analysis at the subregional scale and network-based attribute accumulation at the regional scale in order to process large regions in an efficient manner. For large watersheds such as the Rio Grande/Bravo basin, the raster data is too large to be handled as one entity; this problem is dealt with by subdividing the basins into parts. The results from each sub-basin are merged on the vector side for determining parameters. This methodology helped to verify the validity of dividing a basin for processing without compromising on the accuracy of the parameter values determined. This technique could also be applied at a local level when high resolution data, such as LIDAR data, area available. These data are so dense they typically preclude raster analysis over a relatively small area.

A powerful conclusion from this research is that regional HydroID assignment is critical to the success of regionalization. The HydroID enables the connection between features in the landscape, including the connection of watersheds to outlet junctions, as well as the connection of junctions with next downstream junction. Also, it allows the integration of subregions into regions, through the update of the NextDownID in the most downstream junction in each region.

Acknowledgements

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